An Information Filtering and Control System To Improve the Decision Making Process Within Future Command Information Centres

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Summary

This paper describes the achieved research results within several national and international C2 and information-management projects to develop concepts for balancing the information push with an operator's information need in order to meet the requirement to avoid / suppress information overload situations. The paper starts with an analysis and syntheses of the information overload problem. A model is used to describe the causes and the consequences of information overload on the operator's behaviour and performance in a command information centre of naval vessels. Research has shown that an increasing amount of time is needed for gathering and discriminating relevant information from the actual information push while less time is left for analysing the relevant information in more details and taking correct and original decisions. Information overload is seen as a serious threat for the quality and performance of mission execution. The blueprint for an adaptive information management support concept is based on merging several information management support approaches:

1. Approaches to estimate and/or measure and control the operator's information overload.
2. Information exchange concepts.
3. Information handling within several kind of tasks: Skill based, rule-based and knowledge-based tasks.

Based on the complexity of the problem, an information management concept is discussed to control and filter the information flows adaptively for skill and rule dominated tasks.

1. Introduction

Future Naval Command and Control organisations are characterised by its small staff while at same time naval vessels will operate in an increasingly complex and information rich environment with a high time pressure. Information overload is seen as a serious threat for the performance of future operations.

Current naval command and control concepts are based on an evolutionary continuation of the C2 concepts that have been developed several decades ago. In the last years we have seen that life-cycle costs have become an important design constraint for new command and control concepts. The need to decrease the life-cycle costs will increase in the coming decades. Thosecosts are to a large degree determined by personnel and exploitation costs. It is not an exception that the personnel costs amount to 40% of the total life-cycle costs. Application of the rapidly developing information technology has until now not yet resulted in a substantial reduction of the number of staffing in the Command information Centre (CIC), although CIC staffing and automation vary significantly in different navies.

A reduction of the number of CIC staffing implies at the same time a reduction of the human decision making capability which has to be counterbalanced by an increased capability of the supporting information management system. This factor especially calls for intelligent (support) systems that incorporate skills, knowledge and experience with naval warfare to substitute for the reduced number of operators. Some navies are addressing the issue of CIC staffing by research programmes on Reduced Manning Concepts for future command and control organisations. Examples of such research programmes are 'Smart Ship', 'SC-21' and the Dutch research programme on Future Naval Command and Control Concepts ([Maas and Keus, 1999], [Scott, 2000]). The increased mission complexity and the demand for personnel reduction require innovative solutions and choices in both the automation of processes as well as the management of the information flow in future C2 organisations.

This paper describes the analysis and the design of an advanced information management system to prevent / suppress information overload situations in future C2

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organisations. The paper starts in chapter 2 with a description of a model that shows the causes and the consequences of information overload in the operator's behaviour and performance from an abstract point of view. The paper continues in chapter 3.2 with a projection of the information overload factors and characteristics on the human organisation in the command information centre of naval vessels. Interviews with operational Naval Officers have been used to analyse the model during military operations. Based on this analysis an overview of user requirements is described in chapter 3.3 for an advanced information management support system. A set of high-level system functions is analysed separately in chapter 4 and is translated to architecture of an information management support system. The paper concludes with a summary with respect to filtering and controlling the information flow in future command and control organisations.

2. Information load model

2.1 Introduction

This chapter describes the military implications of a model [Schneider, 1987] of the causes and the consequences of an information overload on the operator's behaviour and performance. This model has been used for criticising the information management concepts on their capabilities to avoid or to suppress information overload situations.

2.2 Description of the information overload process

This section discusses a simplified model of the causes and consequences of information overload in a command and control organisation (Figure 1). For easy understanding of the model we present the following definitions:

- Organisation: The combination of the computer systems, their users and the way they work together.
- User: Any person within the organisation (from operator up to commander), unless specifically indicated otherwise.
- Information overload: The condition at which the information processing requirements exceed the information processing mechanisms available, so that the organisation is unable to process the information adequately [Tushman and Nadler, 1978]. In short: the information-processing requirement is larger than the information processing capacity.

Figure 1 shows that two categories of aspects influence the sensitivity for information overload:

1. Organisational condition aspects.
2. Information overload factors and characteristics.

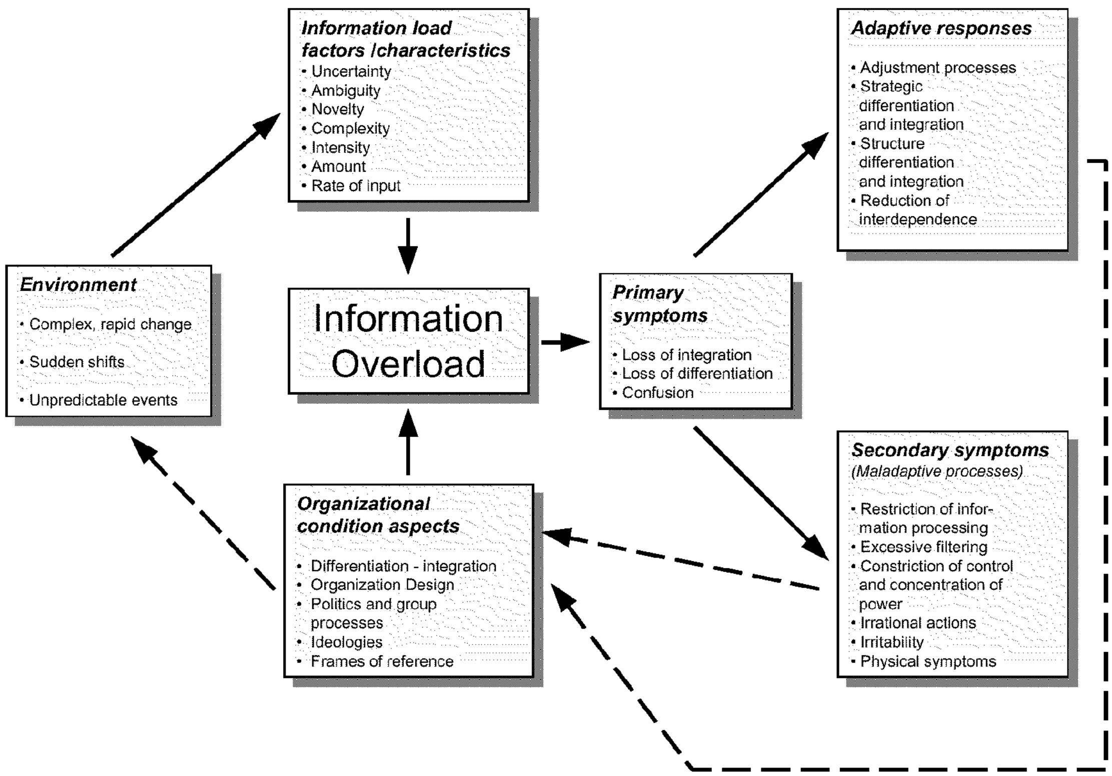

Figure 1. Information overload model [Schneider, 1987]

This first aspect is related to the Command and control organisation. Several organisational conditions influence the sensitivity of the organisation for information overload situations:

Organisation design: the organisation design affects basically how information is processed. For instance, a functionally designed organisation may restrict or distort information flow as it reaches higher levels which may even result in the failure of important information reaching the top of the organisation. A functional organisation requires information to be integrated at the higher levels. An insufficient integration will require extra information processing capabilities at the higher hierarchical levels of the organisation. Within a matrix organisation, the integration of information is mainly carried out at the lower levels. However, more information is generated as the amount of interaction between users increase. In addition, ambiguity may increase, due to different perspectives of the users.

Levels of differentiation and integration: Differentiation ensures that the required specific information becomes available. Defining specialised roles and functions within the organisation that acts as divisional and functional boundaries take care of this. These boundaries act as barriers for the information flows. The lack of boundaries can cause defective filtering, which will result in a failure to screen out irrelevant information.

Integration ensures that the correlation among specific information is recognised and brought to a higher level. The structure of the organisation must take care that the information flows, that carry the information that to be correlated, come together at the right level. Often, gathering information is not the problem, but the integration of information is.

Politics and group processes: Depending on own perceived power, the status of the sender or receiving user, and the extend to which it is seen as furthering or impeding goal attainment the information can be distorted, modified or re-routed. Further, the users may frame certain issues in light of personal or group interests, at the expense of organisational interests.

Frames of reference: Information may be processed incorrectly, at the wrong level, or not al all, because of the characteristic styles of collecting, analysing, and verifying information that is used in an organisation. Ultimately, this may lead to too much information, or less (but too ambiguous) information.

The second aspect is related to the information overload factors / characteristics. Organisations may operate in complex and turbulent environments, characterised by sudden shifts, unpredictable events and complex interdependencies. Such environments may be perceived as uncertain or ambiguous. The properties are not inherent to the environment, but are attributed to the environment by the organisation. The information need of the organisation determines which of the properties of the environment are relevant for the organisation. This implies that the information that must be processed by the organisation can suddenly change. If these changes can be predicted (even if only on a higher level), the organisation and/or the underlying information management system can better adapt to these changes. The information needs are a function of the characteristics of the functional mission and strategy of the organisation, the individual users, group processes and the before mentioned organisational structure and schemes. The sensitivity for information overload situations is determined by a set of factors, which characterises the information flow:

Uncertainty: uncertainty refers to the quantity of information required versus the available information. Insufficient information often results in further information requirements, which often will still not provide the required information, but even increase the information overload even further. Note that, for instance, even a single message may incorporate uncertainty. This can still be regarded as a case of insufficient information, because the message does not contain enough information to make it certain.

Ambiguity: Possible different interpretations of the same information and/or too much information are in conflict with each other. This is often due to interpretation of the same information, in varying contexts.

Novelty: Information is considered to be novel when it does not conform to the current awareness of the situation. Information that is sufficiently novel will attract attention. Information, which is excessively novel, may be ignored because it appears irrelevant or unrelated to the present context.

Complexity: Complexity of information refers to the specific aspects of the environment that can have an impact on the organisation and reflects the inter-relatedness of these aspects.

Intensity: Intensity refers to the increase in rate of information, and/or the importance of certain information. Increased arrival rates could reduce the required time to process information and make correct decisions, thus inducing (potential) information overload. This situation often invokes stress that can stimulate a sense of urgency or overwhelm an individual.

Amount of information: The amount of information is related to the number of meaningful items.

An increase in one or more of the information load factors / characteristics will increase the information processing requirement, and thus may cause an information overload situation. The organisational condition aspects exert a major influence in the information processing capacity.

When an information overload occurs, the organisation will (try to) cope with the overload. This leads to changes (usually restrictions) in the information processing capacity of the organisation. These changes can for example be caused by narrowing of attention, simplification of information codes, or reduction of information channels (in number or in capacity). These changes in information processing are described by the so-called Primary Symptoms. These symptoms can usually not, or with great difficulty, be measured.

The organisational response to information overload may lead to successful adaptation or it may create temporary or perhaps enduring dysfunction. While the Primary Symptoms cannot be measured directly, they express themselves through the so-called Secondary Symptoms and through the Adaptive Processes. The Secondary symptoms are an expression of the maladaptive attempts

to cope with information overload. The symptoms themselves have a negative influence on the information processing capacity of the organisation (this is the negative feedback loop). The organisational responses to information overload situation that lead to a successful adaptation by the organisation are identified as the Adaptive Processes. Like the Secondary symptoms, they are triggered by the Primary Symptoms. The adaptive processes are the cause of a positive feedback to the organisational conditions.

2.3 Observations

The following observations can be made based on the analysis of the information overload model:

- Not all information overload situations can be solved by information technology solutions. The organisation of the human organisation will always be a vital link in controlling the information load of the operator.
- The fact that Primary symptoms are not measurable makes it very difficult to use a robust information flow control concept in the feedback loop to control information-overload situations. In most cases, the user performs several tasks simultaneously. This means that it is very hard to identify the critical user task that is responsible for an information-overload situation even if we could measure the most relevant information factors and characteristics.
- Measuring the Secondary Symptoms is an option for controlling information overload situations. However, we have to be aware that it is an emergency brake for preventing an escalation of the information overload problem.
- The information technology can show benefits in providing support in gathering and selecting the relevant information from the total amount of provided information. This should guarantee that only relevant information would be presented to the user at the right time and in the right way. However, this doesn't mean that information overload situation will not occur in case of presenting only relevant information to the user. It is still possible that relevant information or tasks will overload the user.

3. Problem analysis and synthesis

3.1 Introduction

The previous chapter showed that the organisation and the characteristics of the information flow influence the sensitivity for information overload situations. The paper continues with the military domain analysis of the information load factors and characteristics and discussing technical solutions in next chapter. This chapter discusses the information overload problem in the Command Information Centres in naval vessels during tactical operations. This analysis was carried out by means of interviews and the monitoring of a command team during training sessions. The interviews were carried out on two levels of details. A storyboard was used to discuss the occurrence of information overload situations in general terms while more detailed information was gathered from discussions of the bottlenecks in the execution of specific operational tasks. This paper discusses not the details of the information management problems for specific operational tasks, but they are used to underline the findings of the top-down analysis (generic analysis). This means that the results are not used to start a development process for a decision support tool / system for a specific situation, but that they are used to identify the military requirements that steer the research in generic information management support concepts.

Section 3.2 analyses the occurrence of information management bottlenecks within current and future naval Command Information centres during the execution of operational tasks. A set of user requirements is discussed in section 3.3 that should prevent the command team in getting into information specific overload situations.

3.2 Military analysis of information overload situations

The military domain analysis shows that the information availability and demand in future operations will greatly exceed those of current operations. The number of available information sources and their bandwidths will provide much more information than the current C2 organisations can handle. Information exchange among the C4I systems and their operators puts pressure on both the capacities of the communication links and the capability of the operators to survey and digest the incoming information.

The more information operators receive, the more time they need to assess the value and the relevance of the information in relation to their mission. All this information is converging inside the command information centre, resulting most probably in an information overload for the staff. Information overload situations will pose a serious threat for the quality and performance of mission execution.

Information overload occurs mainly in the execution of rule- and knowledge-based tasks within the orientation and the decision-making phases of the OODA loop. Research shows that (a lack of) time is seen as the most important bottleneck in the execution of these tasks. Too much time is needed to gather the required information and removing the non-relevant information from the total amount of information that is presented to the operator. The remaining time is not enough for operators to use the available information in a proper way to take correct and original decisions for situation assessment and decision making tasks.

Analysis shows that, uncertainty, amount of information, ambiguity, novelty, level of abstraction, time constraints, presentation media and task overload are seen as the most relevant factors for information (over)load. The last four factors are not identified as information overload factors in the literature. Especially the last two are factors that are not inherent to information, but are more related to the operator's status.

- Uncertainty in information severely restricts the possibility of the operator to locate, identify and recognise threats, and to determine and/or predict the intention(s) of the threats. In case of uncertainty, an operator will try to gather more information, or to

correlate existing information, to reduce the uncertainty. Depending on the amount of information that must be gathered and /or correlated, this may cause information overload situations. Uncertain information will only cause stress (and consequently possible information overload), when the information is considered as important.

- The amount of information is related to the total number and/or the rate of information items, in the sense that both have the effect that they can overwhelm the operator with information to be processed, which can result in an information overload situation.
- Ambiguous information only causes stress when the context is not clear and/or that the information conflicts with other information to determine the potential means of a threat to the ship or to the mission. An operator will try to gather more information, or correlate existing information, to reduce the ambiguity. Note that this has to be done at the level of interpretation of intentions, unlike the work that needs to be done to reduce uncertainty, which is at the level of gathering more (sensor) information and/or intelligence reports.
- Novel information causes stress when the information does not conform to the current awareness (and expectation) of the situation, and when the information is digested very late (or even too late). The last situation occurs in situations where the information is enclosed in already known messages. At first, the operator sees no reason to assess the offered information on its novelty.
- The level of abstraction influences the amount of time that is required to process the information. In most of these cases the provided information should be processed to bring the information to the right level of abstraction (which requires extra time) and in some cases the operator isn't able to process the information because of insufficient knowledge to interpret the information.
- Time constraints are not a real factor, in the sense that they are parameters that are attached to incoming information. However, they do influence stress due to the fact that most tasks have hard time constraints. In most cases the operator spends a lot of time in gathering the required information and separating the relevant information from the non-relevant information, and time is also needed to control the decision support tools to assess the information.
- Workload plays an important role within information overload situations. The time and attention that is spent on task execution that has impact on the time and the attention that is required to assess the offered information. For instance, the information gathering process is seen as a labor-intensive process.
- The operator has to deal with different information flows at the same time. For instance, the operator is confronted with three categories of information flow: information that is displayed on the tactical screen, voice information that is provided by his headphone and the presentation of textual messages on paper and in his mail box.

3.3 Military requirements to avoid military information overload situations

The analysis shows that the causes of the information overload can be divided into two main categories:

1. Information gathering: Too much time is required to gather the required information and as consequence there is not enough time left for a correct and extensive assessment of the information.
2. Information assessment and processing: An operator has to execute different tasks at the same time, each of which have their own priorities and information needs. The ensuing problem is that at a given time the operator is fully focussed at the execution of a task and is unable to detect other relevant or threatening events in his environment.

The Information gathering requirements are aimed to deliver support for the collection and aggregation of information from the various information sources. This support should be capable of composing information need descriptions and search support in order to increase the pace of the information gathering process. An example is the requirement for the system to be able to extract relevant information from textual messages and combine this with information contained in various databases. The information should then be available to the operator when his task preparation or execution requires it, thus alleviating the operator from searching for the information himself.

The task execution requirements focus on the reduction of the sensory input to the operator; both visual and auditive sources are covered. An example is the requirement for the system to adapt the level of detail of displayed information with respect to the operator's tasks. This could be executed by intelligent information filtering and displaying techniques that are able to aggregate information to a higher or a lower level of abstraction and placing relevant information on the front and moving the non relevant information to the background of operator's attention. For instance, the contacts that are close together are aggregated into one tactical symbol on the tactical display, and non-threatening contacts are dimmed. The system should be able to generate alerts to the operator, when changes in the tactical situation require him to switch his attention to the new event.

The resulting information management system should therefore address the following topics. The support system should provide a task planning in order to enable the system to optimally present the operator with the correct amount of information at the correct time. A filtering module must be able to derive from the tactical situation and the tasks at hand and the present workload of the operator, how much and in what form the information must be presented to the operator. This leads to an estimation or prediction of the effect of the information reduction on the actual overload.

To conclude, the system should provide support in controlling the actual information flow to avoid information overload situations. Passing only relevant information to the operator is not a guarantee that the operator is not confronted with information overload

situations. The Information management support system should be able to filter the amount of information with respect to the operator's preferences related towards information need and display requirements and his present level of work and information load.

4. System concepts and architectures

4.1 Introduction

This chapter discusses several conceptual visions on information gathering, filtering and information control. The chapter concludes with a describtion of an adaptive information management architecture that should be able to control the information flow between the computer system and its user by means of balancing the user's information need and the available information in the C4I system.

4.2 Conceptual views on information gathering, filtering and control

The information management architecture is based on the analysis of several information management support concepts / approaches:

1. Concepts that estimate and/or measure and control the operator's information load (Section 4.2.1).
2. Information exchange concepts (Section 4.2.2)
3. The kind of tasks that should be supported by the information management support system (Section 4.2.3)

4.2.1 Controlling the information load

There are basically three approaches to cope with and controlling information overload situations:

1. Feedback control
2. Prediction / estimation of the required information and information load
3. A combination of estimating and measuring the information load.

The first concept (Fig 2a) sounds more or less as an obvious solution. The concept assumes that is possible to measure the actual operator's information load. Further, the information management support system should know exactly what kind of information is relevant for the operator and what is not. However, section 2.2 shows that it is very hard to detect the occurrence of an information overload situation by the fact that it is very difficult to measure the primary symptoms of an information overload and to determine which part of the provided information is mainly responsible for the information overload. Further, the information management system should be aware of what kind of information could be removed from and/or added to the information flow to decrease the required information processing capacity of the operator without causing confusion at the side of the operator. The concept shows benefits in situations where the information parts of the information flow could be processed separately and where the available information could be prioritised by the system in advance.

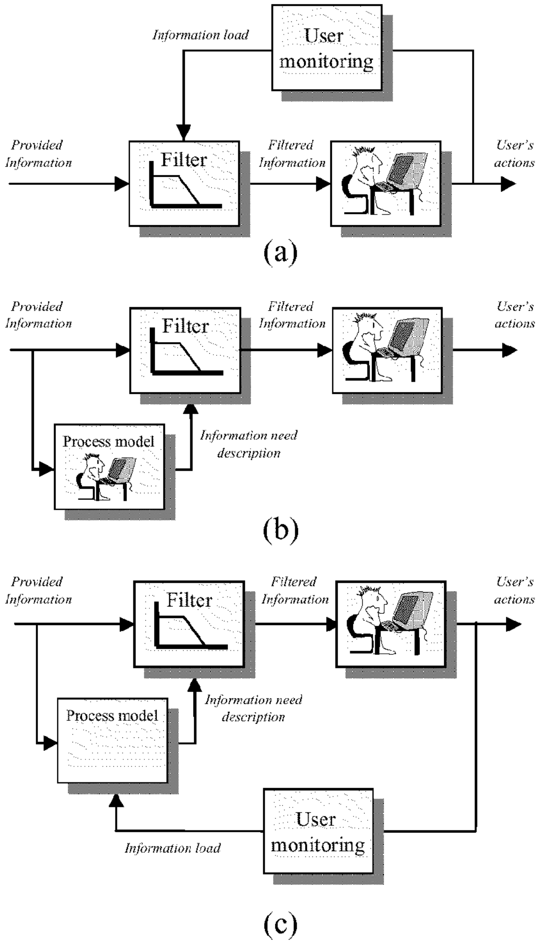

Figure 2. Information control concepts: (a) Feed-back, (b) Open loop and information load prediction control, (c) Combination of feed-back and prediction.

The second concept (Fig. 2b) estimates the required information processing capacity to process the provided information. The information management system should have a model of the processes presenting the tasks that have to be carried out by the operator and which information is needed to perform these tasks and how the information has to be presented to the operator. Basically, the model should contain information about the start conditions (stimuli) to execute a particular task. These conditions are mostly based on the contents of the provided information. For instance the detection of an approaching missile will result in the launch of a sequence of tasks that have to be carried out by the user. Each task will have its own priority and information need that should be made available to the operator while irrelevant information for these tasks should be moved to the background. The process model contains information about the sequence, the priorities and information need of each task, and should make an appropriate planning of which tasks could be carried out without overloading the user. The weakness of this concept is that it is very difficult to define all tasks and put the required details in the model. For instance, the estimation of required information processing capacity for a set of tasks that has be carried out simultaneously is not just a matter of adding the required information processing capacity of each task.

The third concept is a combination of the two above discussed concepts and addresses solutions for the weaknesses of these two concepts. The information filter will be controlled initially by the module that contains process models of the required information and task priorities of each task. A refinement in the control of the information flow is realised by the feedback loop. The concept ensures that the incompleteness and/or impreciseness of the process model can be adaptively refined or temporally modified by means of the feedback loop.

4.2.2 Information exchange concepts

The information exchange between the operator and the different information providers could be established by means of four different concepts (See Figure 3):

1. Report
2. Request
3. Server
4. Broker

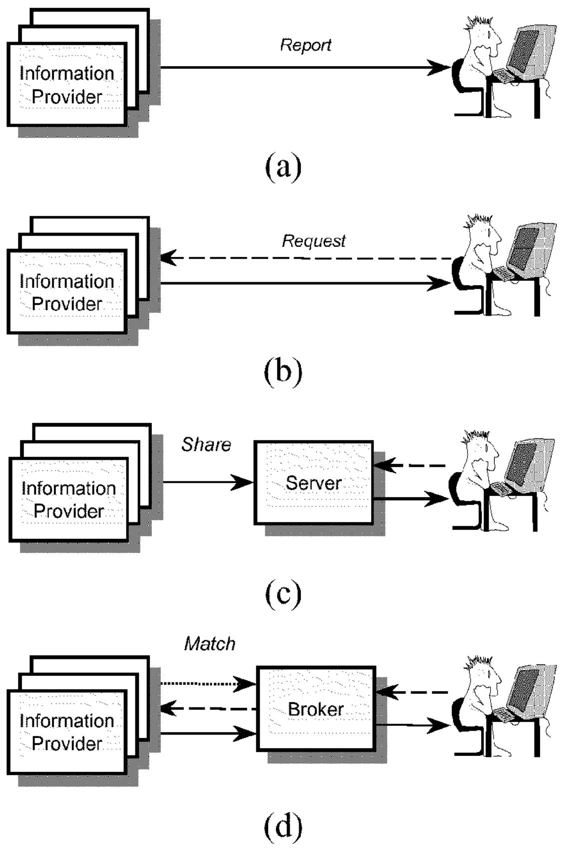

Figure 3. Information exchange concepts: (a) Report; (b) Request; (c) Server; (d) Broker

The first concept ('report'-concept) is the most plain information exchange concept of the four mentioned concepts. Within this concept, the information provider sends reports to the user at a fixed rate without knowing whether the distributed reports have enough relevance for the operator or not at the moment of distribution. This means that this concept is only applicable for situations where the reported information has enough relevance to be pushed to the operator at all times.

The second concept ('request'-concept) differs from the first concept by the fact that the reports are distributed only to the operator in the event of an information request from the operator. The operator should be familiar with the information providers in order to put his information request or he should make his information request to the correct information provider, or he should make his information request public to all accessible information providers. The fact that the operator should know or should investigate what kind of information is available at each information provider makes it a time consuming process. Further, it is questionable whether the operator could reach the information provider to make his information request public all the time, and whether the information provider has the ability to provide the required information instantaneously. The concept shows benefits in cases of loose time constraints and where the operator doesn't have to spend much effort in locating the appropriate information provider.

The third concept ('server'-concept) shows similarities with the previous two concepts. The operator interacts with a local server like he should do with the information providers in the 'request'-concept. The difference is that the operator interacts with only one system (server). The server collects all information from the available information providers that might be used by the operator within a certain period of time. The fact that the operator is released from an external information search and gathering task is seen as a big advantage of the concept. However the disadvantage is that the communication links are not optimally used and could cause data overload situations on the communication links.

The fourth concept ('broker'-concept) meets the disadvantages of the 'server'-concept. The broker communicates with the different information providers whether they could deliver the required information with the required specifications and the information providers have the ability to pass a META-file of the available information to the broker. The information is passed to the broker in case of an agreement between the broker and the information provider. This concept is only applicable in cases where the broker is able to negotiate with the information providers on the information requirement specifications.

4.2.3 Determination of the required information need and support

Operators have to deal with different kind of tasks during the completion of the OODA-cycle (See Figure 4). Rasmussen [Rasmussen, 1983] distinguished three kind of behaviours in controlling the decision making process (See Figure 5): skill-/routine-, rule- and knowledge based behaviour. Using this distinction it is possible to gain better understanding of human errors in running complex processes in an information rich environment and reduce the likelihood of such errors with suitable information management support concepts.

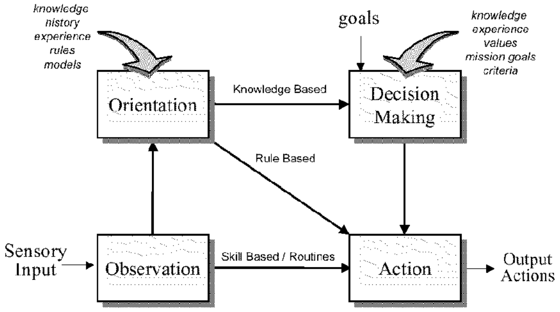

Figure 4. OODA cycle

Skill based behaviour includes expert sensorimotor performance which runs smoothly and efficiently without conscious attention. A dynamic mental model that depicts operator's movements and environment in real time controls this behaviour, and enables the operator to adjust rapidly to feedback from his actions. The tasks that require skill behaviour could be automated easily in most of the cases. However, several tasks require involvement of the operator for confirmation. The information management support system could support the operator by gathering and presenting the required information for getting confirmations from the operator. The information management support system should make it able to perform the skill based tasks more efficiently and rapidly than before.

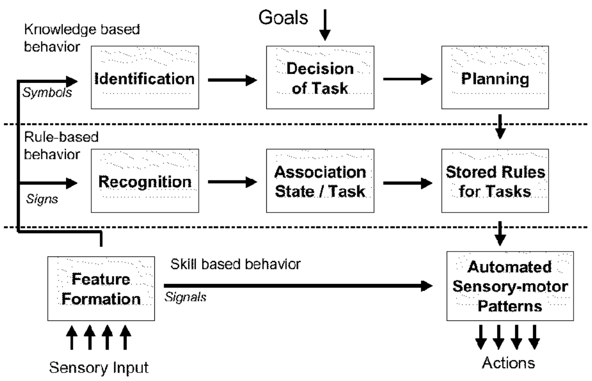

Figure 5: Three levels of human behaviour [Rasmussen, 1983]

Tasks and know-how that can be stated explicitly by the operator will be controlled by a stored rule or procedure. These rules or procedures may have been derived empirically during previous occasions, communicated from other persons know-how as instruction or a cookbook recipe, or it may be prepared on occasion by conscious problem solving and planning. The difference between skill and rule based behaviour depends on the extent to which the task is executed automatically or attentively. Information at the level of rule-based behaviour is processed as a kind of recognition, thereby invoking a rule that dictates the enactment of a certain behaviour (cue-task association) based in experience or formal training. The expertise and the familiarity of the operator define mainly whether the operator is operating at skill-based or rule-based level.

For instance, a defensive action on a single missile attack in open seas should be executed at skill-based level, while a defensive action on a multi-missile attack in coastal waters with many air and surface contacts could be executed at rule-based level (depending on the training and experience level of the operators). The information management support system should support the operator in guiding the operator through the decision making process by presenting all relevant information, and the different options and proposed advises (made by the computer system).

Knowledge-based behaviour is required for complex / novel situations where deeper understanding of the nature of the situation and explicit consideration of objectives and options are required. Information at the level of knowledge-based behaviour is processed as symbols, which are used to construct mental models representing causal and functional relationships in the environment. These models are constructed at different levels of abstraction and decomposition. The fact that the situation is novel and requires deeper understanding means that the information isn't able to determine the required information need in advance. The operator should interact with the information management support system to make the information need knowable to the system. The system could support the operator in the information gathering process and identification of the information need that has to be interpreted to reach a particular goal.

4.3 Design of an adaptive information management and support system

4.3.1 Positioning of the information management system in the C2-organisation

The problem analysis shows that the information management activities should support the operators in performing their situation assessment and decision-making functions. This support ranges from providing support defining the information requirements, in the information gathering process and balancing the presented information with the operator's information requirements. This support should guarantee that only relevant information is presented the right way and time to the right person. This demands a close co-operation with the other systems of the C2 organisation (See Figuur 6).

The communication between the information management support system is bi-directional. The information management support systems present of course the required information for the operators, but should also provide an interface to make the operator's information requirement constraints knowable to the information management system. These constraints consist of META - descriptions of the information need, the presentation formats for the information, and the conditions of passing the information to the operators.

Not all information is available in the database. In such situations, the information management should make an appeal to the C4I systems of the C2 organisation:

Decision Support: The raw information that is available in the database should be further analysed by the dedicated automated situation assessment and decision making analysis tools. The results of these analyses form the actual information need for the operator.

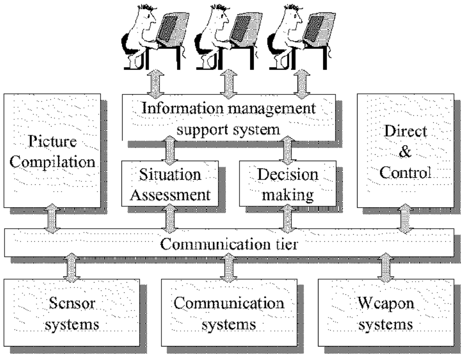

Figure 6. Positioning of the information management support system in relation to the main functionality's and systems of the C4I organisation.

Picture compilation: the available information isn't available in the tactical database and should be gathered from an adequate deployment of own sensor systems and / or should be gathered from other platforms. This requires an information search operation where the required information could be obtained, and /or the best use of all available data / info sources.

The above mentioned actions require a good co-ordination and communication with the involved C4I systems. The C4I systems should be able to react on triggers to start a particular analysis or information search operation, and the C4I systems should be able to notify the information management system that the requested information is available in the database.

4.3.2 The architecture

This section discusses the different processes of the information management support concept in more details. This model is based on results that are obtained within the IFICS project (See chapter 6). An overview of the different modules and their interrelationship is shown in Figure 7. There are five processes that could be identified as the core modules of and the thread for the information management concept:

1. Assessment of environment and provided information
2. Task monitoring and management module
3. User's information need module
4. Filter settings
5. Information Filter

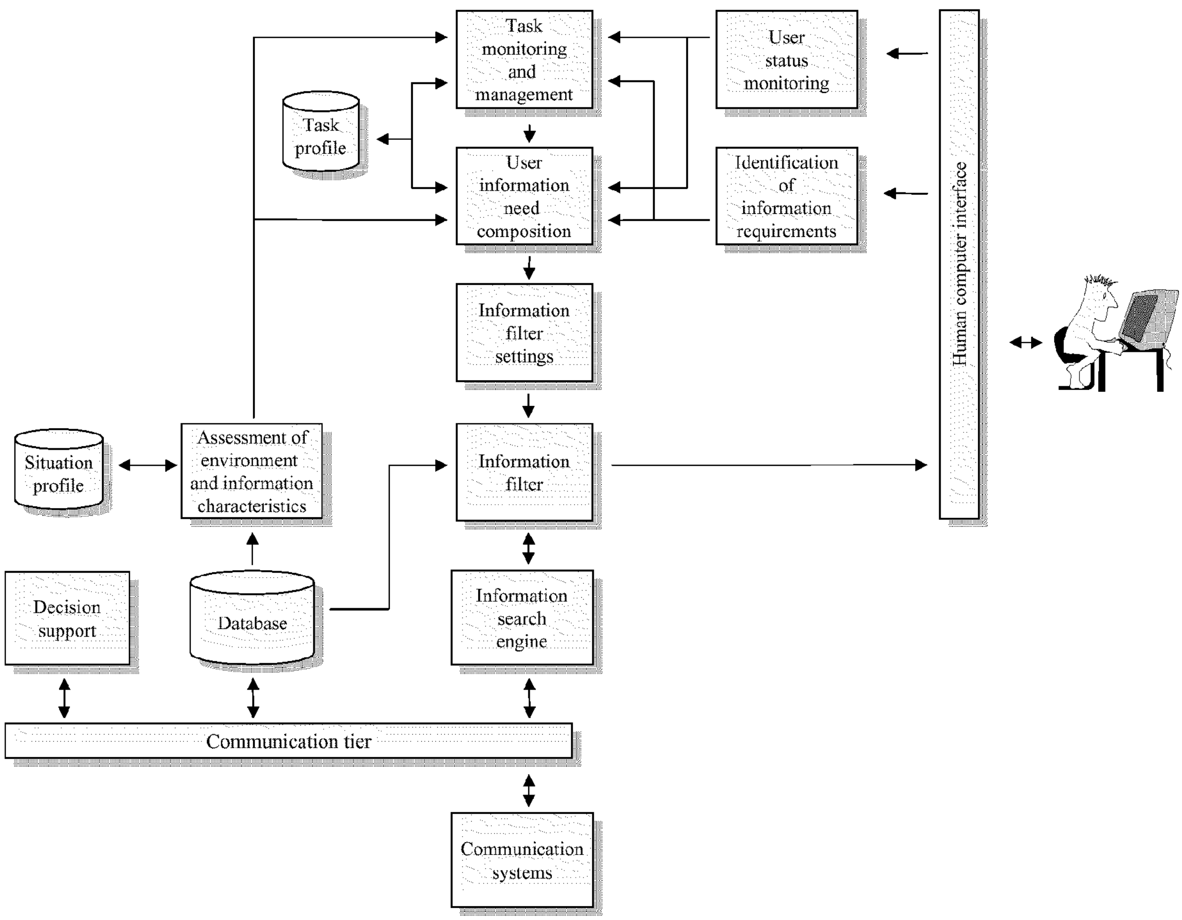

Figure 7. High level architecture of the information management support system

Three databases and four other modules support these five modules:

1. Databases
   a. Situation Profile database
   b. Task Profile database
   c. Tactical database
2. Supporting modules
   a. User status monitoring
   b. Identification of information requirements
   c. Information search engine
   d. Human computer interface

The information assessment module & Situation profile database

The module related to the assessment of the environment and information factors / characteristics assess the situation the environment of events that are important for the C2 organisation. The relevancy of the events is determined by the influence of that event on the mission of the platform. A set of event characteristics and their relevancy is stored in a situation profile database. The load of assessing the environment is expressing by measuring a limited set of the information load factors and characteristics as shown in Figure 1 in section 2.2.

Any system that employs filtering must decide which information to filter. The information that is relevant to the user's current tasks must be emphasised, whereas other information can be dimmed or left out entirely.

The relevance of the information in relation to the user's current tasks is expressed by the values of various attributes of the information. For instance, tracks normally have attributes identity, type (air, surface,...), range, speed, etc., and the user's current tasks will dictate that he is particularly interested in, say, hostile air tracks within a given range (this would be the case for a user performing an Ant Air Warfare task).

However, in some cases, the attributes that determine the relevance are not explicitly available in the information. For instance, the user may be particularly interested in threatening tracks, but the tracks database may not contain threat level information. In this case, it is necessary to interpret the behaviour of the track in order to estimate its threat level.

There may be other reasons to interpret the available information. For instance, the information presented to the user is driven by the events that occur in the environment. Some of these events may be easy to recognise, e.g. the presence of an unidentified air contact, whereas others may be more difficult, e.g. the presence of a formation aiming to protect a high-value unit, which requires an interpretation of the behaviour of several tracks.

The interpretation of information can be divided into interpretation of the environment, by which we have in mind mainly the tactical situation, and the provided information, by which we understand the text and voice messages obtained somehow by the user.

Interpretation of the environment covers recognition of events, e.g. deviation of a track from an established airway, the speed (or any other numeric attribute) exceeding a certain upper or lower threshold or changing a specified amount. Technically speaking, any query to the tracks database could correspond to an event. Release and identification criteria are natural candidates for events. Other natural events include torpedo attack, submarine detection etc. Recognition of more complex patterns e.g. the presence of a formation protecting a high-value unit or various attack patterns, are also relevant. Several recent research projects, notably the EUCLID RTP 6.1 project, have studied a number of tactical analyses making use of advanced techniques from artificial intelligence, e.g. tactical threat evaluation, engagement co-ordination planning, and terrain analysis.

Concerning interpretation of provided information, it is interesting to employ message understanding technology to extract subject or priority information or structured or formatted contents from free-text messages or voice messages. For instance, position and other information might be extracted. In the case of voice messages, voice recognition must also be employed. Entire conferences are devoted to the message understanding field, providing valuable techniques.

Task monitoring and management module & Task profile database

The events detected as relevant will be a trigger for the operator to start and / or complete operator's tasks. The task monitoring and management module monitors the incoming events and determines the information need for every task that has to be carried out and distributes the tasks among the operators whom are qualified to carry out those tasks. The exact task sequence is based on the work procedures, the work-/information overload and the priority of every task. Information about the information-need, the load of each task and the procedures of performing each task is stored in a dedicated task profile database. A META language is used for expressing the information need and its presentation format in the task profile database.

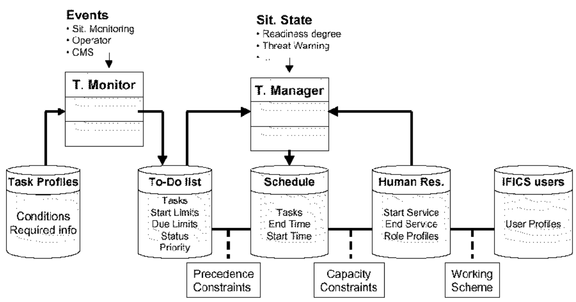

Figure 8: task monitoring and management module

Figure 8 shows the concept behind the task monitoring and management module. The task monitor runs continuously. It handles the incoming events and monitors the deadlines of the active tasks. New tasks are put on the 'To-Do'-list and accomplished tasks are removed from the 'To-Do'-list. The task monitor triggers the task manager if the content of the 'To-Do'-list has been changed. The task Manager calculates a new task schedule by taking the precedence and the capacity constraints of the human resources into account.

The contents of the task profile could be filled easily and in advance for skill and Rule-based tasks. Extra effort is required to define the information need for knowledge

based tasks. Such tasks could be divided into fragments of task sequences or the information need should be specified on-line and stored in task profile database. The operator could activate these task profiles at a later moment.

User's information need module

The user's information need module determines the total information need that has to be presented to each user, instead of determining the information need per task. The total information need is determined by the complete set of tasks that is (to be) executed by the user. The information need module has basically two ways of tuning the information load that is perceived by the user. The first option is to tune the actual amount of information, for instance, only confront the user with information that is required for top priority tasks. The second option is to tune the way in which information is presented: its presentation form. From experiments in the field of HCI, one has learned that some presentation forms are much more demanding than others; for instance, blinking tracks on a TDA attract much more attention than dimmed tracks, thus increasing the perceived information load.

Two aspects influence the information need (including presentation forms) that is determined for a user. The first aspect is the perceived tactical situation. If dramatic things happen in the perceived tactical situation, such as a missile attack on the user's ship, the presentation forms for all tasks may be influenced and it may be decided to give emphasis to the information need of top priority tasks, dealing with self-defence.

The second aspect is information load.As already depicted in Fig. 2, there are several ways to control information. The mechanism developed for IFICS is in accordance with option c) comprising both prediction and feedback. Prediction plays a role by having an information load attached to the information need per task. By summing up the information loads for all tasks, a prediction of the total information load is established. If this predicted information load reaches a particular threshold, it may be decided to remove the information needs for low priority tasks, until the predicted information load is beneath the threshold. Feedback plays a role by actually monitoring the user's behaviour, and delivering measures concerning the perceived information load to the information need module. Based on this feedback, it may now incorporate changes by either manipulating the total information need, or manipulating the presentation forms for each particular information need.

Filter settings module

The user's information need expressions are expressed in generic terms. This means that these expressions could not be used directly to access the used databases before any further processing of the information need expressions. The expressions will be parsed and translated into database queries to access the databases that are used within the C2 organisation.

Information filter module

The information need and presentation expressions are finally interpreted and used for accessing the databases of the C2 organisation, and passing the information to the operator's. But before doing that, the information search engine should provide clearness whether the required information is available within the database or that the information needs to be gathered by own sensors and/or from other platforms.

User status monitoring module

The task monitoring and management module gets feedback about the task progress from this module. The actions of the operator's are analysed to identify relevant events which refers to the start and/or end of tasks and to get a better insight in the actual information /workload of the operator in performing.

Identification of the information requirements module

Not all operators will have the same information requirement for the same tasks. This means that the operator should have the ability to adapt and refine the information need and presentation expressions as stored in the task profile database to meet the operator's wishes. In our concept, the operator is able to define new tasks and fill out the corresponding information requirements (information need, presentation, and start conditions) in a task template. This template will be activated on operator's demand or started automatically when the environmental conditions meet the start conditions as presented in the template of that particular task.

Information search engine

This module looks whether the required information can be found in the available tactical database or that the information should be provided by its own sensor systems and/or decision support systems, or that the other platforms should be asked to deliver the required information.

Human computer interface

The human computer is the physical interface between the operator and the information management system. The task of this module is directed towards the composition of the operator's display with:

1. A graphical tactical display.
2. An overview of all relevant / actual textual messages.
3. An overview of all relevant / actual interaction menus.

5. The IFICS demonstrator

A demonstrator implementing the concepts that have been described above is in the process of being developed. Figure 9 shows a snapshot of the current system.

The demonstrator is composed of a number of agents [Knapik & Johnson] that are tied together in a proprietary agent framework based on Java RMI. Each agent implements one of the modules that were described in Section 4.3.2.

A simulator (whose interface appears in the lower right corner of the figure) is used to demonstrate the functionality of the system. In the snapshot a hostile missile appears on the tactical display (the red track). This has been recognised as an event by the tactical situation agent. Based on this, the task monitoring and management (TMM) agent has fired a missile self-defence task (consisting of a number of other subtasks). The information need definition agent has determined the information required by the user for these tasks. For instance, a pop-up display in the dialog areas prompts the user to select the weapon type to engage the missile, and time-to-first-fire and time-to-last-fire for the various weapon types of the platform are presented.

The system is highly configurable. For instance, it is a simple matter for the operator to change the information needs for each task.

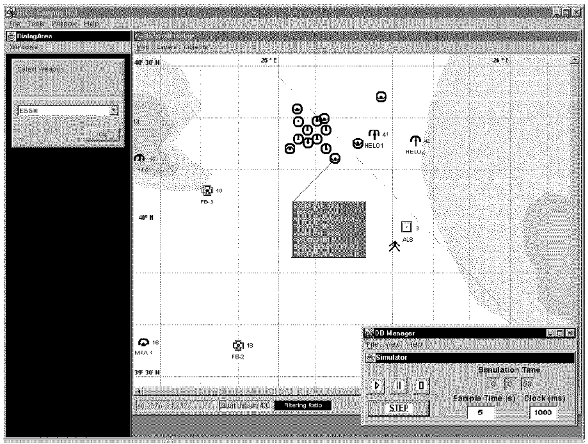

Figure 9: IFICS Demonstrator

6. Summary

The following statements summarise the obtained results:

The information overload problem will influence the performance of future command and control organisations. The structure of the organisation, the environment and the way the information is presented to the operator determine the sensitivity for information overload situations. Solutions for the information overload problem should be found in both in the structure of the organisation and applying advanced information technology concepts in supporting and optimising the information exchange between the computer system and the operator.

Operator support in gathering the required information and discerning the relevant information from the total available information would suppress but not completely avoid information overload situations.

A concept is postulated that could be used to filter and control the information flow among the computer system and the operator. The concept uses predefined templates containing the information need and the presentation formats for each task to support the filtering capabilities of the concept to ensure that only relevant information will be passed to the operator. Operator's load prediction and task progress measurement techniques are used to control the information load of the operator.

The concept is developed for supporting skill and rule based tasks, but extra research is required for supporting the operator in doing knowledge-based tasks. Work done so far shows that the information need and its presentation formats for skill and rule-based tasks could be expressed in advance.

7. Overview of the involved projects

The contents of this paper is based on the research results that were obtained in two research projects:

1. Future Command and Control Concepts for naval vessels.
2. Information Filtering and Control System.

The first research project is directed towards the development of reduced manning concepts for future Command Information Centres of the Royal Netherlands Navy. TNO Physics and Electronics Laboratory and the TNO Human Factors institute carry out this research and are both part of the TNO Defence Research organisation.

IFICS (Information Filtering and Control System) is the name of a European research programme that is carried out as part of the EUCLID (European Co-operation for the Long-Term in Defence) RTP 6.11.1 programme. The IFICS consortium consists of five different companies from four countries: TNO-Physics and Electronics Laboratory, Hollandse Signaalapparaten B.V. (The Netherlands), TERMA (Denmark), DATAMAT (Italy) and INTRACOM (Greece). The research programme is carried out under the management of TERMA. The authors would like to thank the following people for delivering their contribution in the design and implementation of the IFICS demonstrator: Louwrens Prins (TNO-FEL), Lars Stavnem (TERMA), Domenico Pannucci, Luca Onofri (DATAMAT), Georgios Detsis, and Lefteris Dritsas (INTRACOM). The IFICS project started in 1998 to develop a system to avoid information overload situations in the human organisation by means of balancing the operator's information pull with the information push.

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